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ABSTRACT

Students in Papua New Guinea experience considerable difficulty in dealing with much of their work--especially in science and mathematics. The ability to achieve some acknowledged level of excellence is dependent upon cognitive factors. During 1972 a series of pilot studies were carried out in various secondary and tertiary institutions to investigate students' basic difficulties and to develop a set of testing procedures. These studies formed a basis for an investigation in 1973. A battery of "logic/quantitative" tests was administered to seven groups of high school and college students. The tests are described and analyzed in detail. A series of interviews were conducted with a substantial sub-sample of the groups that had taken the tests. A full analysis of the results has not yet been carried out. One of the broad findings of the study has been that students in general perform a good deal better (given essentially the same task) in some contexts than in others. It is as important to build upon students' strengths as it is to take steps to remedy weaknesses. Individual students seem to have a preference for a particular context. A project planned for 1974 will investigate the extent to which students have "preferred modes" of information intake and consider the feasibility of presenting materials in alternative forms. (LS)

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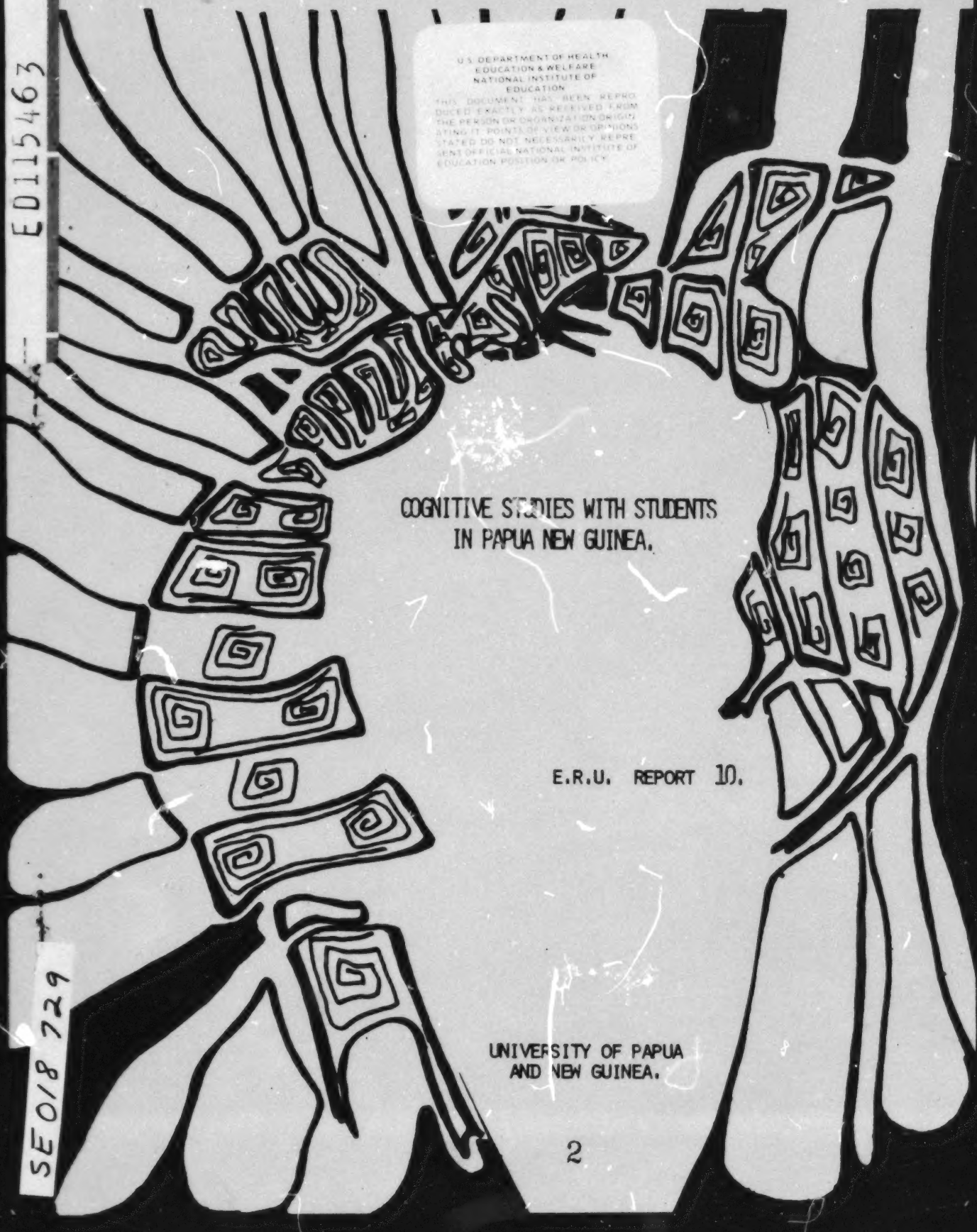

COGNITIVE STUDIES WITH STUDENTS IN PAPUA NEW GUINEA.

E.R.U. REPORT 10.

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Cognitive studies with students in Papua New Guinea.

E.R.U. Report 10.

November 1973

J. Jones
Educational Research Unit

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Firstly I wish to express my thanks to the many teaching staff in the many institutions who assisted in this study, through their help in administering tests, arranging schedules, criticising and discussing procedures and results - and simply for their encouragement. A special thank you to Max Kelly of Macquarie University for his initial help and encouragement, and for the loan of apparatus. Thanks also to Ann Jones who marked and collated most of the tests; and to Cecilia Kone for typing the report.

INTRODUCTION

Students in Papua New Guinea experience considerable difficulty in dealing with much of the work to which they are subjected. This is true for all disciplines, but is probably most clearly marked in the areas of science and mathematics. While a simple *recognition* of this state of affairs is an important first step toward any ultimate solution, it is not enough. To say that someone has "difficulty with mathematics" for example is to make a very broad statement. The ability to achieve some acknowledged level of excellence in mathematics is dependent upon a large number of more basic skills of a cognitive nature. An important factor in any achievment situation is an individual's motivation; however, no amount of motivation can compensate for a lack of the necessary cognitive apparatus. For this reason, the present discussion is confined to cognition - or thinking.

During 1972 a series of pilot studies was carried out in various secondary and tertiary institutions; the aim of these was to take a first broad look at students' basic difficulties, and also to develop a set of testing procedures which could be used in a wider context. Some of these studies have already been described in fair detail while others (generally of a more limited and inconclusive nature) have not been reported in print. A very brief description of some of these studies, and the main results, is given below.

(a) A battery of tests dealing with the concept of proportionality was administered to UPNG preliminary year students. (This study is described in E.R.U. Report 6).

The reason for the choice of proportionality as an area for investigation was:

(a) its practical importance in many fields of study

(b) the logical basis which has been proposed as underlying it. (Inhelder and Piaget, 1956).

The main results which stemmed from this study were (i) that students on the whole experienced a great deal of difficulty in handling proportionality and (ii) that a generalised proportionality factor was a correlate of academic success at UPNG. This investigation also enabled some useful test-item modifications to be carried out.

(b) An English test, designed to investigate how far students were comprehending some very common words and constructions of a "logical/quantitative" nature was administered to a wide range of students. A full description of this initial investigation is given in E.R.U. Report 4; overall, the results which were obtained indicated that there were serious difficulties which could be detrimental to students' comprehension of logical/quantitative expositions. On the basis of these results, a revised version of the test was produced.

(c) A series of short "logic" tests was administered to later year students at UPNG. The aim of this was simply to produce a series of test items, in a variety of contexts, which were as unambiguous as possible; a number of tests were developed out of this.

(d) A series of individual interviews in which subjects

were asked to carry out tasks of a logical nature, in a concrete situation, was carried out with Form 2 and Form 4 students in a local high school. The conceptual difficulties which the subjects seemed to be experiencing were something of a revelation (to the author at least) and indicated that a substantial, in-depth investigation of this nature would be required.

On the basis of these studies, a considerably extended and more comprehensive investigation was planned for 1973. It was fairly obvious that two distinct components would be needed.

(i) A battery of "logic/quantitative" tests which could be administered to large groups of students.

(ii) A series of interviews with a substantial sub-sample of the group included under (i), so that a more direct picture could be obtained.

This investigation has in fact been carried out, and while a full analysis of the results is not yet complete, enough interesting data has emerged to make an interim report worthwhile. A feature of the group testing programme was that, as much has possible, the subjects' teachers were involved. In each case, the tests were shown to the teachers beforehand for comment and discussion, and the testing programme was integrated into the regular routine as far as possible.

A further object of this report is to give a fairly complete description of the individual testing programme which was used. A number of requests for details of aspects of the programme have been received; and it is hoped that

the description given will stimulate others to experiment themselves; certainly, for me it was a fascinating and illuminating experience.

It is worth emphasising that this *is* an interim report: some of the results have not yet been received, there are thousands of completed paper and pencil tests and hundreds of hours of individual testing to analyse. All of this amounts to a lot of data, and while a rough overview can indicate broad directions, it is likely that a fuller analysis will yield the most valuable information in terms of specific modifications, directions and alternatives which might be desirable. This will be the subject of a future report.

THE TESTS AND THE SAMPLES.

The tests.

Following the description of the item which is characteristic of the test, a brief rationable for the test is given. This has been kept as brief as possible: further enquiries will be welcomed, as will requests for copies of any of the tests, which are available from the author.

1. The Group Tests.

1A. (i) "*Tall* is to *height* as *heavy* is to _____?"

(Ten items)

(ii) "If eight bicycles cost $440.00, how much would three bicycles cost?" [ ]

(3 items)

(iii) "Three people stay at a hotel for a week, and the bill is $210.00. How much would it cost for eight people to stay at the same hotel for five days?" [ ]

(3 items)

(iv) *Six* is to *nine* as *eight* is to _____?

(8 items)

Ratio and proportion items which are heavily dependent upon English language; the numbers involved are quite simple.

1B. (i) A man spends R cents each on three bottles of beer, and P cents on a packet of cigarettes. How much will he now have left if he started with D dollars?

A. D- 3R - P cents

B. 100 x (D-3R-P) cents

C. 100 D - 3R - P cents.

D. $\frac{D - 3R - P}{100}$ cents

(4 items)

(ii) A man's car can travel Y miles on one gallon of petrol. If he drives for X miles, how much petrol will he use?

A. XY

B. $\frac{X}{Y}$

C. $\frac{Y}{X}$

D. (X + Y) (3 items).

The 1B (ii) items involve proportionality in the context of algebraic symbols rather than numbers; the 1B (i) items involve the same skill in "translating" from English to algebra, but do not involve proportionality.

1C. (i)

4	14
2	7
8	28
?	63

Missing number = [ ] (6 items).

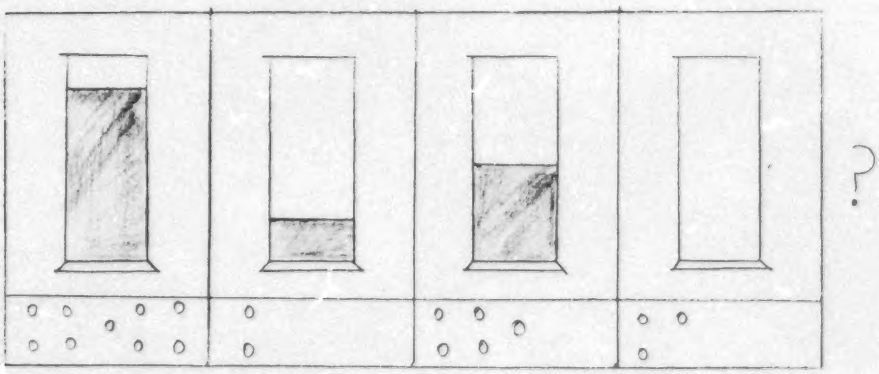
(ii)

9	16
3	10
15	22
?	11

Missing number = ☐ (8 items).

The 1C (i) items involve proportionality in a context which is practically independent of the English language, but is heavily dependent upon number. The 1C (ii) items are similarly dependent, but involve linear relations rather than proportionality.

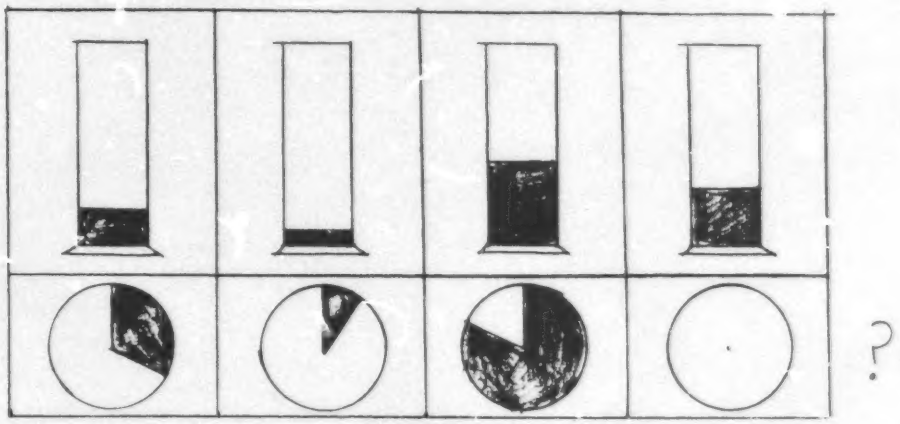
1E.



All of the items call for the recognition of proportionality between an analogue (shaded portion in the above example) and a number of dots. The ability to handle the items is practically independent of English and independent of number as an *abstract* entity. (All of the

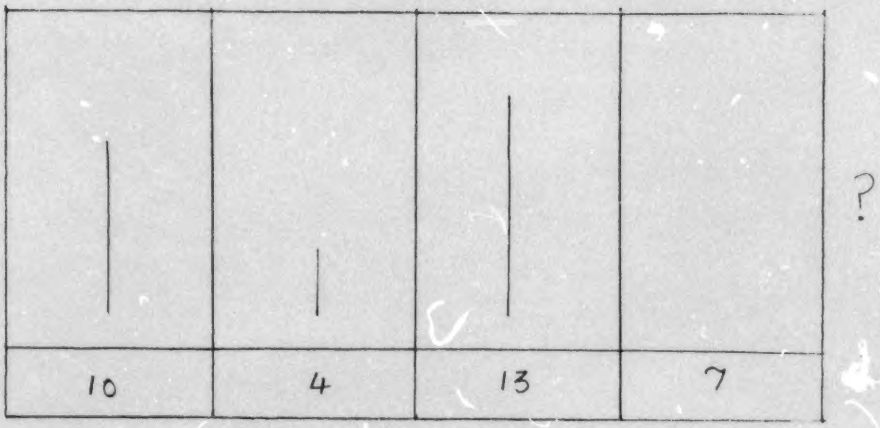
items involved *direct* proportionality). Subjects were instructed to answer quickly, drawing in freehand, and not to use measuring instruments.

1F.



The items require subjects to be able to handle proportionality between two "analogues" (shaded portions in the item shown); the ability to handle this is practically independent of English language and number. Two of the items involved inverse proportionality (ie. one quantity gets smaller as the other gets larger - $p \times q =$ constant), and the instructions were as for 1E.

1G.



In this case the task is that of handling a proportionality between a number, as an abstract concept, and an analogue (length of line in the item shown). The items are practically independent of English language. One of the items involved a squared relationship, the others all involved direct proportionality. The instructions were as for 1E and 1F.

2A. "When a certain switch is pressed, sometimes a bell rings and sometimes it doesn't; when the switch is left alone, the bell doesn't ring"

If the bell rings, the switch has been pressed.

Yes No Can't say. (5 items)

Subjects were required to circle the appropriate response according to whether the statement in the box was "definitely true", "definitely false" or "impossible to say".

These items (and those of 2B, 2C, 2D) are dependent upon the ability to draw valid conclusions from evidence which is presented. Basically it is that ability which is required, in the scientific method of enquiry, to judge whether or not data supports a particular hypothesis. An ability to handle propositional logic - though not in the formal sense - is implicit in the ability to handle these items. All of the items involved two variables only. All of the items are heavily dependent upon English language.

2B. "There is a certain white liquid which turns yellow when certain chemicals are added to it. We take some chemicals labelled "A" and "B" and carry out some experiments".

Experiment "A" and "B" are added - the liquid stays white
"A" is added on its own - the liquid stays white.

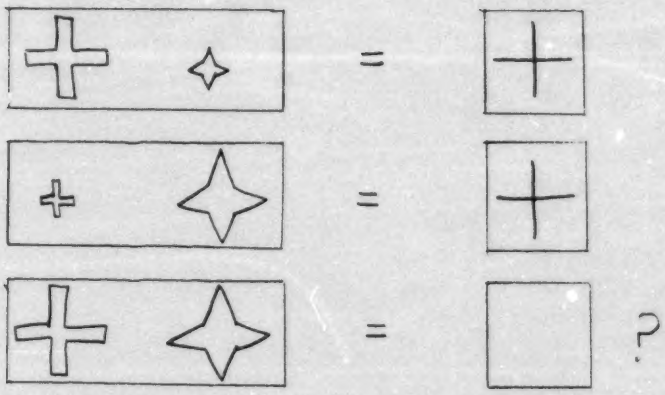
If B was added on its own, the liquid would stay white

Yes No Impossible to say.

(6 items)

The abilities called for in answering the items are ve y similar to those required for 2A; the items in this test all had a definite "scientific" flavour while some of those in 2A did not. Three of the items involved three variables, the remainder involved four variables; they were therefore that much more complex than the items of 2A.

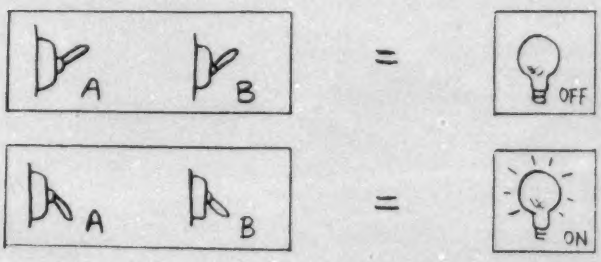
2C.



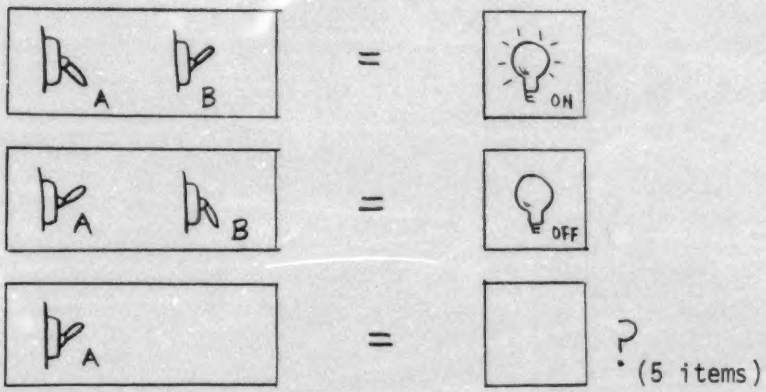
(5 items)

Subjects were instructed to draw in the correct figure if they were able to ; if they considered that it was *impossible* to work out a specific answer, then they should write "Impossible" in the space. It was stressed that "Impossible" should be written only if it really were impossible for *anyone* to work it out. Again, the skills called for are similar to those of 2A and 2B (basically, an ability to handle propositional logic), but this time in a context which is very largely independent of English language.

2D.



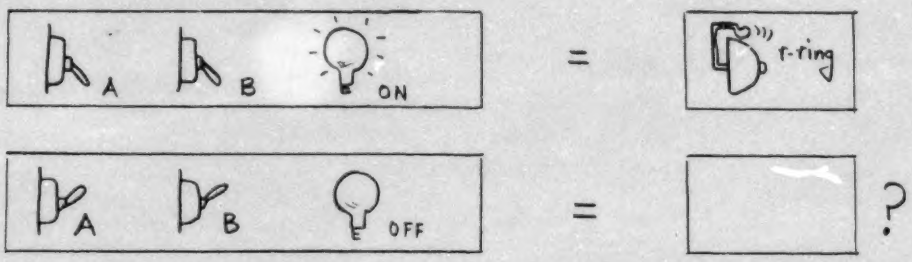
2D (cont'd)



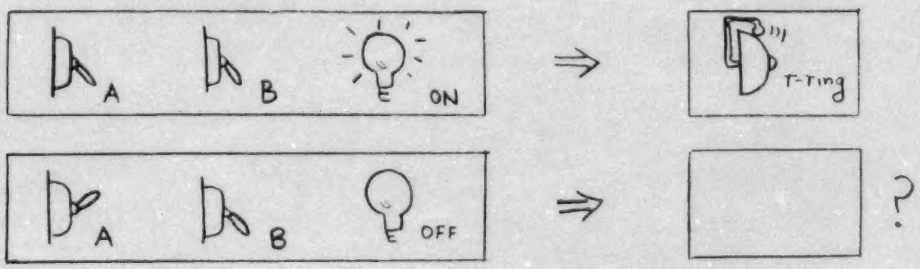
(5 items)

The instructions to subjects were exactly the same as those for 2C ; also the "logic" skills involved were identical, apart from the fact that the problem has now been framed in a more practical context with which subjects are likely to be more familiar. It is, in fact, a language-free version of 2B in many respects.

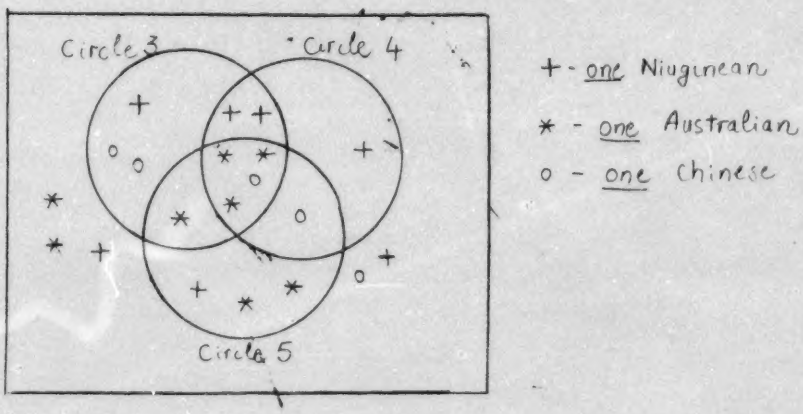
During some discussions which were held at Goroka Teachers' College, regarding the testing programme, there was a concensus of opinion that tests 2B, 2C, 2D were too difficult in that they "tricked" students into the wrong answers. For example, an item from 2D was as follows.



Now, a persuasive (but fallacious) logic is to insist that the bell will *not* ring in the second case, since *everything* has been changed; as a matter of fact it is impossible to predict the outcome in the second case. Accordingly, tests 2B, 2C, 2D were made "easier", by revising them so that there was no obvious pattern which directed students toward fallacious conclusions when conclusions were in fact impossible. In the revised 2D test, the above item became:



2E.



The diagram shows all the people who were inside a

shop at a certain time.

People inside Circle 3 own cars
People inside Circle 4 are more than 40 years old
People inside Circle 5 smoke cigarettes.

1. There are three Niugineans more than 40 years old who own cars. | True | False | Uncertain |

2. Eleven people smoke pipes. | True | False | Uncertain |

3. There are seven Niugineans less than 40 years old who do not own a car and do not smoke cigarettes. | True | False | Uncertain |

(21 items in all).

In fact, the 21 items were divided over three separate diagrams (the one illustrated is the most complex), i.e. the test was in three parts with maximum scores of 5, 8, 8.

In effect, it is a classification task which is heavily dependent upon English language.

2. The individual testing schedule.

All of the individual testing was carried out by the author, with one subject at a time present. The same order of presentation of the tests (except where indicated) was maintained for each subject, and the mode of presentation of the problem was the same for each subject. However, the exact form which the interview took was dictated by the subject's responses at each stage, and in this respect each

of the situations was open-ended. This was the whole point of using an individual technique. All of the interviews were tape-recorded. The length of each interview varied considerably according to the subject; it ranged from about 45 minutes to about 2 hours.

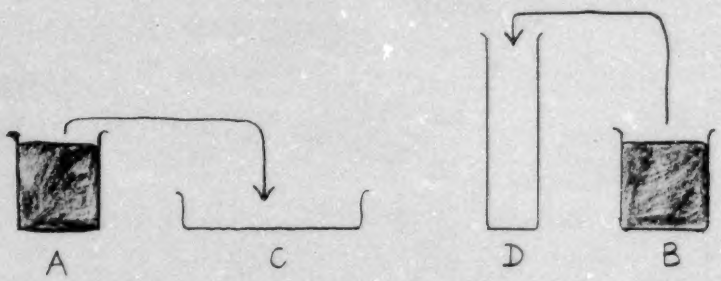
1. Conservation tasks.

(a) Length.

To determine whether subjects realised that length of a piece of wire remained constant when it was (i) linearly transposed (ii) rotated and (iii) bent.

(b) Quantity.

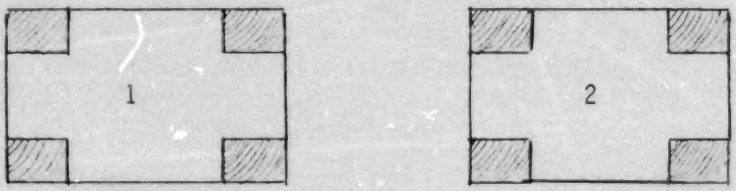
To determine whether subjects realised that the amounts of rice in beakers A and B (which the subject first agreed were identical) remained the same when they were transferred to C and D.



(c) Area.

Subjects were first asked whether the areas left over (unshaded) were the same when four identical blocks (shaded) were placed on the corners of two pieces of board of the same size. (Actually, the board was presented as "a piece of ground" and the

blocks as "houses"). All subjects agreed that the amounts left over were the same.



It was then determined whether subjects realised that the areas remaining were the same

(i) when the blocks of board 2 were arranged in a straight line down one edge; blocks on board 1 remained in the same place.

(ii) when the blocks of board 2 were arranged randomly over the board; blocks on board 1 remained the same.

(d) Volume.

Subjects were presented with two metal cylinders, one of aluminium and one of stainless steel, which were exactly the same size. They were allowed to handle these for some time, and then asked which was the heavier; the steel cylinder was indicated in every case. The steel cylinder was lowered into a tall flask of water and the rise in water level marked. Subjects were then asked to predict where the level would rise to when the aluminium cylinder was immensed. (It will, of course, rise to exactly the same level).

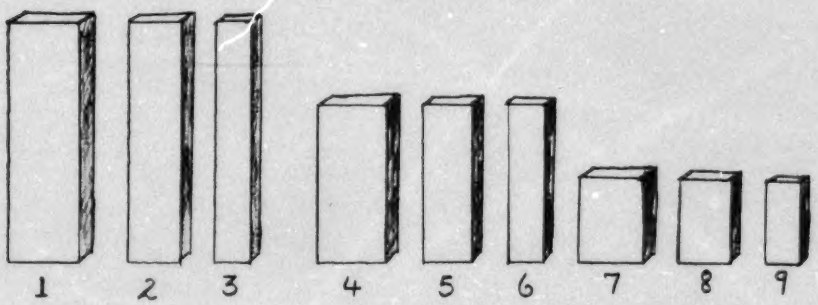
The ability to conserve physical quantities is

obviously crucial for an understanding of practically the whole of the science programme in high schools and tertiary institutions. (Some of the primary science course also requires such an understanding)

2. Bruner Matrix.

This is described in detail by Bruner et. al. (1966; p. 156); the task is illustrated below.

1	2	3
4	5	6
7	8	9



Wooden blocks of different heights and thicknesses, as shown, were arranged in a 3 x 3 matrix as shown. The procedure was as follows.

(a) Subjects examine the matrix.

(b) Blocks 4, 5, 6 are removed and jumbled; the subject is asked to replace them.

(c) Block 1 is left on the board, all the other blocks are removed and jumbled; the subject is asked to replace the blocks.

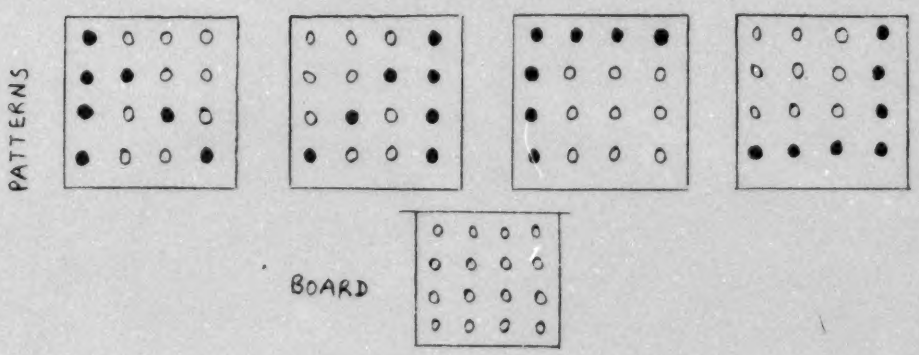
(d) All blocks apart from 1 are removed and jumbled; block 1 is then shifted to position 9, and subjects are asked to replace the blocks to make the same pattern that existed previously.

In order to cope successfully with the task, the subject needs to be able to classify on the basis of two attributes (height and thickness) and order the array accordingly. This "multiple ordering" is basic to a full comprehension of many situations involving relations between two or more variables.

3. Conceptual strategies.

(i) Button board.

This is described in detail by Olson in Bruner et. al. (1966); the task principle is as follows.



The board can be programmed so that any desired button lights up (due to a bulb located underneath the clear plastic button) when it is pressed. Subjects are required to find out which of the displayed patterns has been programmed onto the board, by pressing as many buttons as they think necessary. In the example above (which is only intended to illustrate the principle - the actual patterns used were rather more complicated as they were displayed on a 5 x 5 matrix) it is only necessary to press *two* buttons.

e.g. if we press the button in the top left corner, and it lights, then the pattern must be one of 1 or 3. Pressing any other single button in the top row then enables us to say straight away which of 1 and 3 it actually is (if the button lights, it's 3, if it doesn't it's 1).

Subjects were scored as to which of three broad strategies they adopted.

(a) Analytical - pressing a minimum (or slightly more) buttons.

(b) Partial pattern - where a whole *section* of a pattern is pressed out before a decision is made.

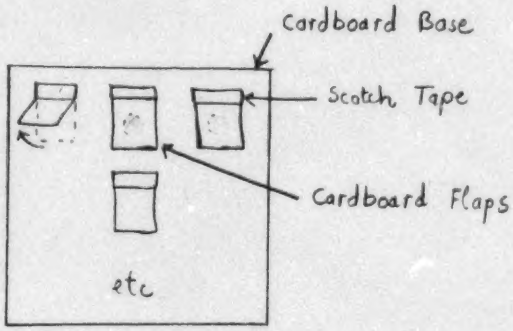
(c) Pattern - where a total pattern (and sometimes every button on the board) is pressed before a decision is made.

(ii) Flap Board.

The task is precisely the same as described previously; this time though, instead of pressing buttons, the subject lifts cardboard flaps to confirm the presence - or not - of a coloured dot. This

system has the advantage of cheapness and ease of construction.

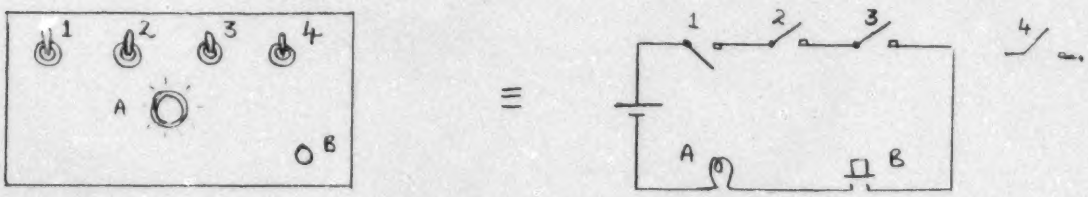
THE FLAP BOARD.



Subjects' performance on the Flap and Button boards was correlated; the correlation coefficient was greater than 0.80, indicating that in effect the two pieces of apparatus measure the same thing.

The skills involved in solving this sort of problem analytically are the same as those required to carry out a qualitative analysis in chemistry, or to locate a member within a taxonomy. Basically it is a case of "asking the right question" to get the information which will give the maximum payoff.

4. Combinatorial thinking.



A box has 4 togle switches, a push-button, and a bulb as illustrated on page 20; the circuit is as shown. The subject's task is to make the bulb light up. He is also required to explain the functions of

(a) Switch 1 - a reversed switch.

(b) Switch 4 - which is not connected to the circuit and thus has no effect.

This situation is equivalent to a physical arrangement, where several variables have to be manipulated to produce a desired effect. Effectively it tests subjects' ability to recognise that various combinations of variables exist, and that the effect of these various combinations has to be assessed in order to come to a full understanding of the situation. In addition, subjects have to carry out very simple experiments and draw valid conclusions from these, in order to ascertain the functions of switches 1 and 4.

5. The balance (proportionality)

Subjects were required to bring a simple balance to an equilibrium position when different weights (in the form of metal washers) were suspended from the two arms. By free investigation with the balance they were required to explain "how the balance worked". The "rule" for the balance is: $W_1 \times L_1 = W_2 \times L_2$, where W and L refer to the weight and its distance from the fulcrum, for each arm of the balance. This is an obvious proportionality situation, in that the ratio of the weights is the same as the ratio of the lengths. Subjects could "solve" the problem at one of two levels.

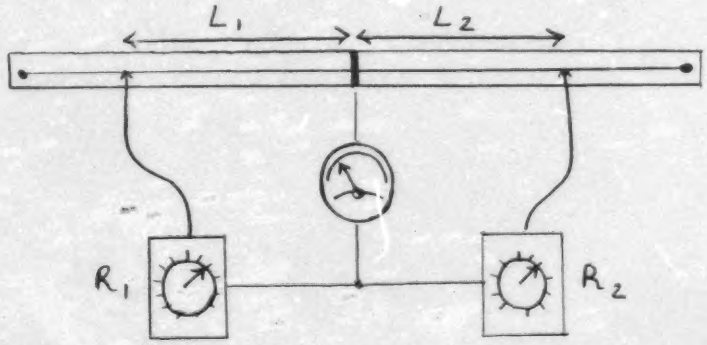
(a) qualitatively: big weight x short length = small weight x long length.

(b) quantitatively: where the numerical equivalence of the products was recognised.

This task was simply to assess the extent to which subjects were able to handle a proportionality relationship in a context with which they were familiar. (All of the subjects tested had "learned" the balance at school).

6. The wheatstone bridge (proportionality).

This was simply a "black box" version of the balance task, set in a context with which subjects were not familiar.



The Subjects' task was to balance the arrangement (bring the needle on the meter to zero) by altering L_1, R_1, L_2 and R_2; the way in which these variables could be altered was demonstrated to the subjects before they

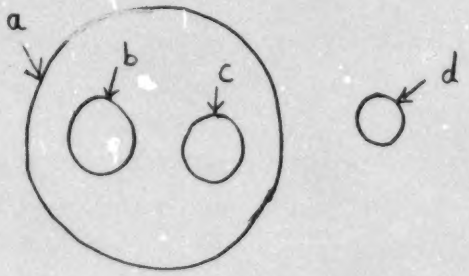
started playing with the system. The balance position for the set-up occurred when:

$$L_1 \times R_1 = L_2 \times R_2$$

and as such it is entirely analogous to the balance situation.

7. Classifications.

This task was complementary to that of 2E. (see p. 13 and 14). In this case subjects were given several concepts, and then required to construct the appropriate Venn diagram describing their relationship. (All subjects were tested for their knowledge of Venn diagram representations prior to this). As an example, subjects were required to draw the diagram for: (a) things we eat. (b) meat. (c) kau-kau. (d) tables. The correct answer is:



Subjects were asked to construct three such diagrams.

8. Logical thinking in "social" contexts.

The interviewer read out loud (and the subject

followed on a printed sheet) a simple short story of about 300 words, which described a dispute between management and workers at a sawmill. Eventually this lead to a strike. Subjects were then asked for their opinion regarding various aspects of the situation, and asked to justify their answers. Examples of the kind of question asked were:
"Do you think the manager was fair to his workers?"
"Was it sensible for the men to go on strike because of what had happened".

The aim was to see the extent to which subjects were able to take an overall view of the situation and combine the various pieces of information available to them in arriving at a solution.

Hallam (1967) has described in detail a method for analysing responses in this kind of situation.

2. The samples tested.

(a) Group tests.

*1. ~150 UPNG preliminary year students. This was a random sample, tested during the first part of the first semester.

*2. ~100 Goroka Teachers' College first year students, taken randomly, and tested during the first half of the year.

*3. ~70 Goroka Teachers' College second and third year students (all of whom were studying mathematics) tested during the first half of the year.

4. 62 University of Technology first year students, taken randomly, and tested during the first half of the year.

5. 61 form 4 students in an urban high school in Lae, tested during the middle of the year. This represented the whole of the 4th form.

*6. ~ 60 form 4 and form 5 students in a large urban comprehensive school near Swansea in U.K. tested at the beginning of the year. (This represents a fairly typical sample from a "semi-deprived" area in Britain).

*+7. ~ 300 form 5 and form 6 students in a senior high school, tested at the end of the year.

* - Not all subjects did all tests.
\+ - Results not yet available.

(b) Individual testing.

(a) 16 UPNG preliminary year students, at the beginning of the year, some of whom have done the group tests, some of whom have not.

(b) 44 senior high school students, during the middle of the year. Eventually, they will all have completed all the group tests.

(c) 59 form 4 pupils in an urban high school, during the middle of the year, all of whom have completed the group tests.

RESULTS AND DISCUSSION

It has already been mentioned that a full analysis of the results has not yet been carried out; broad results only will be quoted, and discussion will tend to be in wide rather than specific terms. A detailed report will follow in due course, when a full analysis of the data has been accomplished.

A. The group tests.

Table 1. Mean scores on the group tests items for the different samples.

Test	Means					
	A	B	C	D	E	F
ERU Eng.	n.a	25.1 [5]	19.3 [5]	n.a	n.a	n.a
1A (i)	9.09	7.16	6.38	7.31	6.96	7.24
1A (ii)	2.92	2.15	1.36	1.93	2.59	2.69
1A (iii)	2.31	0.91	0.57	0.80	1.33	1.60 (1)
1A (iv)	3.24	1.92	0.77	0.78	2.43	2.95
1B (i)	1.72	0.95	0.62	0.64	1.06	1.02 (2)
1B (ii)	1.31	0.99	0.57	0.88	1.14	1.38
1C (i)	3.14	1.22	0.84	1.14	1.78	2.05 (3)
1C (ii)	4.16	1.25	2.03	1.98	3.53	3.04
1E	5.78	5.36	5.01	5.55	5.65	5.86
1F	5.74	5.09	4.56	5.53	5.41	5.67
1G	5.60	4.80	4.51	4.99	5.33	5.17
2A	3.02	1.99	1.72	2.03	2.11	n.a
2B	1.88	2.27	1.25 (4R)	1.62	1.54 (4R)	n.a
2C	1.42	1.09	0.90	0.84	0.80	n.a
2D	1.20	1.29	1.13	1.35	1.19	n.a
2E (i)	n.a	4.57	3.85	4.14	4.49	n.a
2E (ii)	n.a	6.66	5.77	5.73	6.80	n.a
2E (iii)	n.a	6.30	4.77	5.47	6.39	n.a
	(N=58)	(N=97)	(N=61)	(N=94)	(N=51)	(N=62)

(Standard deviations have been ommitted, for the sake of simplicity).

A:- British group; average age ≃ 15 years
B:- UPNG preliminary year; average age ≃ 17-18 years
C:- High school, form 4; average age ≃ 16-17 years
D:- Goroka, year 1; average age ≃ 18 years
E:- Goroka, years 2 and 3, average age ≃ 19-20 years
F:- University of Technology, year 1, average age ≃ 17-18 years.

Notes: 1 - Mean time for this group = 32 minutes
2 - Mean time for this group = 25 minutes
3 - Mean time for this group = 26 minutes
(shorter times were allocated other groups -) see below.
4 - Revised tests, see p. 12, consisting of *four* and not *five* items as with the other groups.
5 - The revised version of the E.R.U. English test, which has not been discussed in detail. (See below.)

For the "logic" tests there is not much difference between the British and the indigenous groups, but when the proportionality items are taken into account, the groups may be classed (speaking relatively) as follows.

1. "High" performers - British group.
2. "Middle" performers - UPNG, Goroka Teachers' College, University of Technology.
3. "Low" performers - High school, Form 4, group.

Some brief comments on the results obtained for each of the items now follows.

ERU English. The UPNG preliminary year sample performed quite significantly better than the Form 4 group; in broad terms the results were very similar to those described in ERU report 4. Many quantitative and comparative terms gave a lot of difficulty, and in particular the conditional - "if --- then" - construction was very badly understood.

Tests 1A. Overall, the British group performed much the best. The University of Technology sample, performed next best, but for them the test was *untimed*; the average time taken by this group was 32 minutes (based on half the sample who filled in their time of completion), which is very much longer than the 12-15 minutes which was allowed for all the other groups.

On the whole, test 1A (i), dealing with relationships between concrete concepts, described through the English language, was handled much better than the questions which dealt with relationships between more "abstract" quantitative concepts, described through English language. It is also interesting to note how much more difficult the indigenous samples found 1A (iii) compared with 1A (ii). Checking back to the test item description (see p. 5) will make it clear that the items are dependent upon the same kind of English and arithmetic skills. Conceptually however the 1A (iii) items are more difficult in that an extra multiplicative relationship is involved; for example, in the illustrative item the concept of a "person-day" is needed to deal with the problem. This seems to make the items relatively much more difficult for the Papua New Guineans, as compared with the British schoolchildren.

1A (iv) was done badly by everyone; the extra time

spent by Sample F seemed to give them a big advantage over the other indigenous group. This improved performance due to the extra time is not so straightforward as it might appear, since most of the other groups seemed to have attempted the majority of the questions, and their poor performance did not on the surface appear to arise out of their having insufficient time to complete the tests. However, it does appear as though a more relaxed and unhurried approach gave the group a distinct advantage.

One further point of note is the extent to which the year 2/3 Teachers' College subjects perform better than their year 1 counterparts. However, it must be remembered that the year 2/3 subjects were all studying mathematics as an option, and are thus a selected group.

Tests 1B.("translations" - English to equations: p.6)

These items were not answered well by any of the groups. The inability of students in PNG to "translate" from one mode of communication to another (English to equations, equations to graphs, etc) has given rise to considerable concern; the results of this particular test tend to indicate that the concern is justified. An interesting point to note is that the proportionality items (1B (ii) - 3 items) caused less difficulty than the other items (1B (i) - 4 items) which did *not* depend upon proportionality.

Tests 1C. (proportionality, abstract numbers: p.6)

This test, which is dependent entirely upon the

ability to recognise direct proportion and linear relationships in a "pure number" context, probably demonstrates the area in which the British sample enjoys the biggest advantage over the Papua New Guinean group - particularly on 1C (i). During quite a large number of discussions with teachers of science and mathematics in PNG, the remark has frequently been made that "numbers cause Papua New Guinean students to switch off" - or something very similar. Certainly these results do nothing to refute this claim.

Again it is worth noting that the more "leisurely" approach of the University of Technology group gives them something of an advantage over the other Papua New Guinean samples. But, taking a longer time does not necessarily lead to a better performance - there was no correlation between time taken and achievment, for subjects for whom the data was available.

Tests 1E, 1F, 1G. (proportionality, analogue situations: p.7)

Apart from the fact that these items are framed in a more concrete, perceptual situation, the "proportionality" skill called for (ie. an ability to see a constant relation between relations) is identical with that called for in test 1C (i). Yet, the fact is that the Papua New Guinean groups perform very much better on these tests (as do the British subjects). So, to some extent it would appear to be the *abstract concept of number itself* which causes the difficulty. Whether this is the whole problem is another matter, since even on these tests, the British subjects perform rather better. However, the results which have been obtained certainly suggest that there is some merit in

the suggestion which was tentatively put forward in ERU Report 6. That is, in teaching proportionality relationships (or any other functional relation), numbers should be introduced gradually after the relationships have been intuitively seen, in a qualitative sense through the use of physical analogues.

A few observations from around the market-place might also give a clue as to some of the difficulty experienced in dealing with direct proportion. Usually, "food value" and "price" do not bear a direct proportional relationship to one another; for example, at Waigani market a paw-paw costing 20¢ is only about 50% bigger than one costing 10¢; a paw-paw which is twice as big as a 10¢ paw-paw mgiht well cost 30¢. The same sort of thing is usually true of mandarin oranges. And just recently I was assured, despite much expression of incredulity on my part, that the piece of sugar-cane of length about 6 feet was indeed 20¢, while the piece which must have been about 4½ feet was only 10¢! (Both pieces were the same thickness). It seems as if in many cases an extra value "out of all proportion" is added to an article simply because it is bigger. There are plenty of examples of this in Western society too (gem-stones for example), but they tend not to crop up in every-day contexts.

Test 2A. (logical deduction, using English: p.9)

This is a test of very simple logic, which is heavily dependent upon English; some of the test items closely parallel those used in the English test. The British group performs the best.

Test 2B. (logical deduction, using English: p.10)

In this case there is not nearly so much variation across the groups, and indeed, the UPNG preliminary year sample performs rather better than the British group. The kinds of skills needed to deal with the items are just those which are needed to deduce valid conclusions from experimental data. On the whole it was answered poorly by all the groups; the main fault was that subjects jumped to conclusions which were not justified on the basis of the data which was available to them. There was very little difference in the performance on the original and revised versions of this test. The revised did not suggest a "pattern" of results leading to a fallacious conclusion, as did some of the original test items. However, even when there was nothing in the way of a pattern of results, students still jumped to conclusions which were completely unjustified.

Tests 2C, 2D. (logical deduction, using diagrams: p.11)

Much the same results as for 2B were obtained. Papua New Guinean students performed better on test 2D (the more readily-recognised physical context) while the reverse was true for the British group. An interesting point to note is that the UPNG preliminary year group does much better on 2B than on either of 2C or 2D, despite the fact that 2B is heavily dependent upon English language, while the others are not; there is little in the "logic" test results as a whole to support any suggestion that English language difficulties play the major role in stifling achievment.

The kinds of skills tested by 2B, 2C, 2D (particularly

2B, 2D one could argue) are crucial for coping adequately with much of the science which is currently taught in secondary and tertiary institutions in PNG (and other parts of the world). The whole of the "guided discovery" method of teaching depends upon the ability of a student to draw valid conclusions from gathered data. If a student is *not* able to extract the valid result from a set of experimental data, then it becomes a case of accepting the validity of the result, on trust, from the teacher - in which case it would probably be less confusing in many cases for the teacher to simply tell his students the result in the first case. This is *not* an argument against the guided discovery method - it *is* an argument for a more careful consideration of the logical skills that students are expected to employ in specific situations.

The general lack of success of students in coping with these problems must be a cause for concern, and could well suggest that some re-directions in teaching programmes are required. It is cold comfort to point to the fact that the British sample couldn't cope with them either; they were, after all, a very young and rather undistinguished group, the great majority of whom will certainly not go on to tertiary studies.

Test 2E. (classification, Venn diagrams: p.13)

The results which were obtained on this test were (to the author anyway) rather surprising. All the Papua New Guinean students coped with them rather well, despite the extent to which they depend upon rather complicated

English language. This is a task which students are good at - it might well be possible to capitalise upon this in teaching programmes.

B. The individual tests.

The results for the individual tests will be dealt with in sections, starting first with the conservation tasks. Table 2, below, gives the data for the three groups tested.

Table 2. Success in dealing with conservation tasks.

Task	A (N=16)	B (N=44)	C (N=59)
1. Conservation; Length	56%	73%	64%
2. Conservation; quantity	88%	98%	95%
3. Conservation; area	81%	75%	51%
4. Conservation; volume	12%	36%	3%

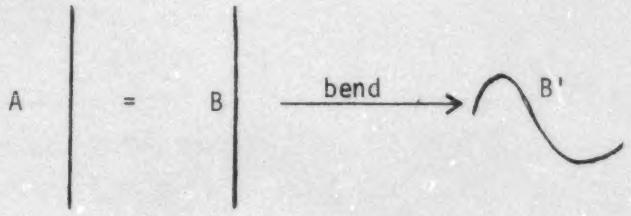
Note: The method of testing is described from p. 15 onward; all parts of the test were required to be performed correctly, before it was counted as a "success".

A:- UPNG preliminary year students.
B:- Senior high school, Form 5 students.
C:- High school, Form 4 students.

At this stage, the following broad observations are possible.

1. A significant minority of subjects tested were not conserving length in all situations. The context which caused most trouble was that where a straight piece of wire was subsequently bent - many subjects did not realise that the bent wire still retained the same length.

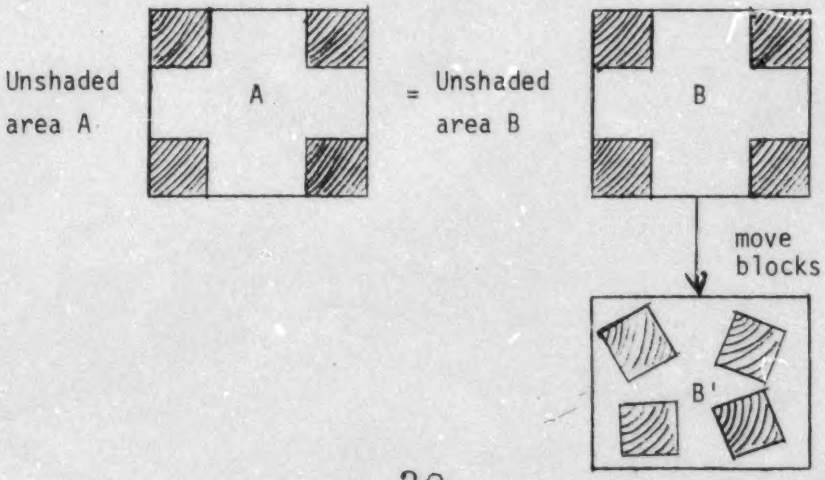
ie.



Many subjects predicted (after agreeing that A and B were the same length) that A was longer than B' (or vice versa).

2. There is little difficulty in the conservation of continuous quantity.

3. Many subjects are not conserving area, particularly in the sample of Form 4 students. The situation which gave the most trouble was the following.



Many subjects predicted, after agreeing that the unshaded areas of A and B were equal, that:

Unshaded area A > Unshaded area B'.

and this would appear to be a perceptually dominated judgement; at first glance, the "ordered" area left over in A does appear rather more than the "randomized" area of B'.

4. The great majority of subjects were unable to deal with this situation, most of them predicted that the lighter cylinder would cause the water to rise by a smaller amount, even though the two cylinders were exactly the same size. Nearly all of the subjects were unable to handle in an integrated way the concepts of weight, volume and density. This is a very disturbing result, particularly since all of the subjects could state that they had "done" density during science lessons, and professed to be familiar with the situation.

In the total sample there were very few subjects who were able to deal successfully with all of the conservation tasks. For at least one of the tasks the majority of subjects were unduly influenced by the "perceptual" characteristics of the situation.

Table 3. Success on the Bruner Matrix task.

UPNG preliminary year.	81%
Senior High School, Form 5.	68%
High School, Form 4.	59%.

The high school sample performs most poorly, with the University sample coming out the best. Overall, it is surprising how much difficulty subjects experienced in dealing with this problem - an ordering according to two attributes does not, on the surface at least, appear to be unduly taxing.

Table 4. Proportions of different strategies adopted in the button-board and flap-board tasks.

	Button			Flap		
	Pattern	Partial	Analytical	Pattern	Partial	Analytical
A	31%	31%	38%	38%	50%	12%
B	43%	25%	32%	36%	41%	23%
C	n.a	n.a	n.a	32%	64%	4%

Note: For a definition of the various strategies, see (p.18).

A:- University preliminary year.
B:- Senior High School, Form 5.
C:- High School, Form 4.

The performance of the groups on the Flap-board was rather inferior to their performance on the Button-board. Overall, the results are not encouraging, with a majority of subjects opting for a perceptually - rather than an analytically-based strategy. An ability to ask the right question at the right time is essential for the efficient solution of practically any problem; in this context at

least, most subjects did not appear to possess the ability. (The basic skill needed to succeed in this task is very similar to that required to play "Twenty questions" - it would be well worth-while investigating how efficiently students are able to operate in an alternative context which does not lend itself so readily to perceptual biases).

Table 5. Performance on the combinatorial task

	1	2	3
UPNG preliminary year.	12%	56%	32%
Senior High School, Form 5.	45%	43%	12%
High School, Form 4.	22%	42%	36%

1, 2 and 3 at the heads of the colums refer to a rough scoring procedure as follows.

1. Got the bulb to light, and explained correctly the functions of the "dud" and "reverse" switches (when asked).

2. Got the bulb to light, and explained correctly how *one* of the dud and reverse switches operated.

3. Either failed to get the bulb alight or could not explain the function of the dud or the reverse switch.

Table 5 indicates that the Senior High School group performed the best on this task. One of the main observations which arose out of this study was the extent to which subjects were unable to draw valid conclusions from experimental data. (In many respects the task of determining the function of the two switches was a real-

life version of tests 2B, 2C, 2D - see p. 10 onwards). A depressingly common example of fallacious reasoning was the following, in the position where the three switches (neglecting the dud) were in the position for making the bulb light up.

(a) Dud "off", press the button - Light comes on.
(b) Dud "on", press the button - Light comes on.

Conclusion: "This switch (the dud) is the main switch".

On questioning subjects further, the reasoning seemed to be something like "The light comes on no matter what we do to this switch, it must be a very "powerful" switch - probably the one which controls all the others". This means that the whole idea of an experimental control was lost on students who responded in this way; the results lend weight to the remarks which were made earlier regarding guided discovery. (see p. 32).

Table 6. Proportionality: the balance and the wheatstone bridge.

	Balance			Bridge		
	1	2	3	1	2	3
UPNG preliminary year.	19%	37%	44%	50%	44%	6%
Senior High School, Form 5.	14%	43%	43%	35%	43%	2%
High School, Form 4.	37%	47%	16%	n.a	n.a	n.a

1, 2 and 3 at the heads of the columns refer to a rough scoring procedure as follows.

1. Got the individual operations for balancing only, but didn't combine them in any way, or get the idea of qualitative proportion. (See p. 22)

2. Got the concept of qualitative proportion.

3. Got the concept of quantitative (or metric) proportion.

Only a minority of subjects, particularly in the Form 4 group, were able to demonstrate that they understood the "rule" for the balance, in quantitative terms; and this was despite the fact that all of the subjects reported that they had "learned the balance in science". The proportion of subjects who were able to transfer their knowledge of the balance to an analogous, unfamiliar situation was very small, as the results for the Wheatstone Bridge indicate. In many cases, students were able to trot out some plausible-sounding jargon, only to later display their total lack of comprehension of the physical situation. As an example, a number of subjects who talked about "clockwise and anti-clockwise moments" failed completely in their attempts to find an equilibrium position for the balance when there were different weights on the two arms. (One such girl spent some time in trying to find a balance position by moving both weights along the *same* arm!).

Overall, the results which were obtained in this context tend to indicate that the difficulties which students experience with proportionality are (in part, at least) "real" conceptual problems and are not entirely due to English language or number problems. But this is *not* to say

that such problems are unimportant, particularly in non-practical situations. A basic problem seems to be that rote-learning measures, or "survival tactics" as Johnson (1972) has so aptly named them, have been largely substituted for any kind of real comprehension. This is no new observation, but the extent of the trend is rather disturbing.

The Classification tasks. (see p. 23)

In general, students found these problems much more difficult than those of 2E, in the group situation. That is, they seemed to find it much easier to operate within a ready-made classification system than they did to construct their own classification systems on the basis of prescribed attributes of familiar concepts. This is perhaps not surprising.

Again, in this context, there was a lot of evidence for "learning without understanding". All of the subjects tested were very familiar with Venn diagram representation, through their work in mathematics. Subjects' answers to questions, their explanatory comments, etc. were liberally sprinkled with the jargon of set theory; "universal set", "union", "intersection" - and yet in many cases these were being applied in a totally wrong fashion to the concepts and their attributes which were under discussion.

One point which was very striking was the extreme difficulty which many of the students had in generating examples of things which would be found in certain areas of the diagrams. (ie. in generating concepts characterised by

specific attributes). For example "A living thing which does not walk on two legs","A human being who does not speak English or pidgin" both proved to be too much for quite a large number of subjects; they just could not think of any examples. It could well be that a more "divergent" approach to the study of classifications and the like would be beneficial.

The interview in a "social" context. (See p. 23).

So far, only the roughest subjective assessment has been carried out. All that can be said is that students varied a good deal in their ability to gather together the various strands and come to a reasoned opinion. Some adopted a very comprehensive overall view of the situation, others "fixed" on one aspect, making all judgements in terms of this, and neglecting other facts which were available to them.

SOME CONCLUDING REMARKS

There are a number of assumptions associated with any instructional programme or teaching strategy. For example, in starting off on a piece of work, one invariably has to make *some* assumptions about a students' grasp of concepts and particular skills and abilities. If these assumptions are incorrect, then right from the start there is little hope of the objectives of the programme being achieved. A number of the results from this study indicate that there are quite probably areas where unjustified assumptions *are* being made about what students are capable of. Take the task involving the conservation of density: most tertiary students are unable to cope with this, although they have covered the topic of density (in some detail in most cases) at high school. A similar result is obtained with the balance situation.

However, it is possibly in the area of students' logical skills that some of the most serious wrong assumptions may be made; particularly in the area of science. At the most basic level, science in concerned with two things:

(i) *Concepts*, which are used to talk "efficiently" about the kinds of natural phenomena with which the discipline is concerned; things like mass, energy, force, etc. are concepts which are basic to the study of physical science.

(ii) *Relations between concepts* - usually in the

forms of generalisations or "laws". (Newton's second law, for example, describes a generalised relationship between the concepts of *mass*, *force* and *acceleration* for an object).

The "scientific method" is simply an approach which is aimed at the determination of some specific general relationship between concepts, and ultimately this is the kind of skill which science (and other disciplines too) aims to teach. However, in order to draw valid conclusions from the results of experiments a form of propositional logic is involved; and it has already been pointed out (see p. 33) that if students do not have an implicit grasp of the required logical operations, then many of the objectives of the programme are being subverted. It is almost certainly true to say that, judging by the results of this study, the majority of secondary and early tertiary students in PNG do *not* have the requisite logical skills. (Neither did most of the subjects in the British sample, judging by the results of the paper and pencil tests).

Part of the problem could be due to the fact that teaching programmes frequently seem to attempt to teach concepts through procedures which are also concerned with the establishment of relations between concepts. This can be very confusing to students. Take the following example:

We have two liquids in two separate beakers marked A and B, and we test each of the liquids with some *grokle*, which is a white solid. We know the following facts:

when grokle is tipped into a clag it turns black

when it is tipped into a kluk it stays white.

The two liquids in the beakers are tested with the grokle, and it is found that the liquid in A has no effect on the grokle, while grokle tipped into B turns black.

Some trypkithilum (shiny looking stuff) is then dropped into each of the beakers, marked A and B. The trypkithilum dropped into B has no effect, while that dropped into A causes the liquid to froth up, and eventually the trypkithilum disappears.

Question: what do you deduce from this?

Answer: plastics disolve in kluks, but not in clags. (Did we forget to mention that trypkithilum was a plastic? Sorry!).

This is not all that easy to follow. But, replace clag and kluk by acid and base respectively, grokle by litmus paper and trypkithilum by magnesium say, and we have exactly the situation which young students are confronted with in science lessons. Why is the real-life situation so much easier to handle for science teachers? Precisely because we are very familiar with the concepts of acid, base, litmus as an indicator, etc. and we *know* what is going to happen all the way along the line; we also *know* what the result of the experiment/deduction process is going to be. However, for a student who is meeting this situation for the first time the whole thing is very confusing; he doesn't know what the result is going to be - he is expected to deduce it from the sequence of operations. And framing the deductive exercise in a context which abounds with strange-sounding names only complicates the situation unduly - clag, kluk and trypkithilum are likely to be almost as meaningful to the reader

as acid, base and magnesuim (as concepts) are for the average secondary science student in PNG.

Really, this kind of teaching procedure attempts to get over three separate things. (a) an understanding, (through familiarisation), of the basic concepts involved. (grokle, acid, clag, litmus, etc.) (b) a piece of knowledge concerning a relationship between these concepts. (c) a familiarisation with a procedure (experimentation-deduction) through which "pieces of knowledge" may be obtained. There is an argument to be made that it is impossible to do all three concurrently. Instead, what should possibly be happening is the following.

1. Students should learn new concepts and become thoroughly familiar with these simply by being presented with positive and negative examples of the concept.
2. Students should learn inductive and deductive logic, in simple situations, in terms of concepts with which they are already familiar.

Only after 1 and 2 have been achieved should a progression be made to situations where "pieces of knowledge" concerning the concepts are deduced as a result of experimentation. The basis of the argument is that it is not feasible to do three jobs at once.

Just recently, a young lady told me a rather touching story about her own confusion over concepts during Physics lessons. When she was a small girl, she'd read a story about a botanist who had been collecting specimens in an

alpine region. In an attempt to reach a particularly rare specimen he started to climb down a cliff, got into difficulties, and slipped. The subsequent story line went:

"As he fell, he gathered momentum".

For our young lady, this conjured up a rather strange picture of an incredibly devoted botanist plucking some sort of flower as he fell down the cliff.

It was when momentum was introduced in Physics that the real confusion started! Eventually the poor girl reached the conclusion that there were *two kinds* of momentum - one a sort of flower, and the other something to do with things moving. And it wasn't until a long time later that the blinding flash - how the two things tied together - finally came. The point of the story is that learning concepts, with their strange new names, and becoming familiar, with them is a difficult and confusing business; the difficulty of the job should not be aggravated by attempting to squeeze in "skills" learning at the same time.

Another way of looking at the situation is in terms of wrong assumptions about students, which has already been mentioned above. If a teacher's assumptions about a student's conceptual development or logical ability are unjustified, in that his expectations of the student are too high, then right from the start there is going to be a communication gap between student and teacher; and as the programme progresses, a compounding of confusion will almost certainly result, with accompanying frustration for both teacher and student.

In an attempt to improve students' abilities to deduce valid results from given information, a pilot project, funded by the Department of Education is being mounted in a number of high schools during 1974. A range of materials, largely in the form of board games which students can play against one another, is being developed. To succeed in these games, certain logical skills are required; the hope is that by playing the games the desired skills will improve. Whether such abilities will in fact develop, and whether they can then be meaningfully transferred to real-life situations remains to be seen.

One encouraging piece of evidence has been reported by Chidzey, working with students at Lae Technical College (private communication). The items of tests 1E, 1F, 1G (see p. 7) were used as an introduction to the concept of ratio and proportion. Students were taken through the analogue:analogue, analogue: number of dots, analogue : "abstract number" representations, in sequence, and only after these had been mastered was the problem tackled in an "abstract number" : "abstract:number" context.
Although not a game, in the strict sense of the word, this situation is in fact similar to an approach which is being tried through one game where the object is to collect sets of different representations of the same ratio, (expressed as areas, numbers, slices of pie diagrams etc.).See also p. 30.

One of the broad findings of the study has been that students in general perform a good deal better (given essentially the same task) in some contexts than others. This is a potentially fruitful area for further

investigations. It is as important to build upon students' strengths as it is to take steps to remedy weaknesses. A further point which has been noted is that individual students, in many cases, seem to have a preference for a particular context. The idea that students are individuals is nothing new - but even so the process of individualising instruction by giving students a choice of material to follow, in order to reach the same end-point has been much-neglected. (An obvious - and to some extent valid - reason for this is the amount of extra work involved in programme preparation). A project which is being planned for 1974 will investigate the extent to which students have "preferred modes" of information intake (written work, pictorial, oral, etc.) and further consider the feasibility of presenting material in alternative forms, so that students may utilise the form they find most comprehensible.

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